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The Effects of Climate Variability on Livestock Revenues in Kenya

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The Effects of Climate Variability on Livestock Revenues in Kenya

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Productive Sector Division

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Abstract

This study examines the effects of climate variability on livestock in Kenya. It uses the Ricardian cross-sectional approach to measure the relationship between climate variability and revenue from livestock. Livestock revenue is regressed against various climatic, livestock diseases shocks, and socio-economic and response variables to help determine the factors that influence variability in livestock revenues. This study is based on data from ASDSP household baseline survey of 10,341 livestock farming households interviewed across the country. The empirical results show that climatic variables (temperature and precipitation) have significant effects on livestock revenues in Kenya. The livestock revenues are affected negatively by increases in temperature and rainfall. An important policy message from the empirical findings is that there is need to come up with measures to address climate-related risks such as livestock diseases and pasture in order to cushion livestock farmers against extreme climatic events and contribute to increased livestock production and productivity.

Abbreviations and Acronyms

AEZs	Agro-Ecological Zones
ASALs	Arid and Semi-Arid Lands
ASDSP	Agricultural Sector Development Support Programme
DFZs	Disease Free Zones
FAO	Food and Agriculture Organization
GCM	Global Circulation Models
GDP	Gross Domestic Product
IPCC	Inter-governmental Panel on Climate Change
KALRO	Kenya Agriculture and Livestock Organization
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KMD	Kenya Metrological Department
NDMA	National Disaster Management Authority
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme

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1. Introduction

1.1. Background

Climate change refers to the state of the climate, which can be identified by changes in mean and/or the variability of its properties that persist for an extended period, decades or longer. Climate variability, on the other hand, is variations in the mean state of the climate (Inter-governmental Panel on Climate Change - IPCC, 2007; 2001). The current climatic variation has significant effects on agricultural production, constraining agricultural income and forcing farmers to adopt new agricultural practices in response to altered conditions. The risks of future climatic changes such as higher temperatures, changes in precipitation and increased climate variability can result in significant effects on both crops and livestock (Molua et al., 2010).

Globally, livestock is likely to face serious effects of climate change and variability, including the risk of extinction of between 20-30 per cent of all animal species. Climate variability has severe impacts on the environment, more so on water availability, agriculture and food security, human health and biodiversity. The IPCC's report of 1990 pointed out a global average increase in temperature of between 0.15 and 0.3°C per decade. It is predicted that greenhouse gas emission could rise by between 25 and 90 per cent globally by 2030, and temperatures by 3 per cent by the year 2050. It is further predicted that even with a small temperature rise of 1-2.5 per cent, the consequences could still be severe, exerting far-reaching effects on the livelihood of many people (IPCC, 2007).

Like the rest of the world, Africa is already a continent under pressure from climate stress, and is highly vulnerable to the effects of climate variability. It is estimated that one third of the African people already live in drought-prone areas and that 220 million are exposed to drought each year. African countries are prone to greater impacts of climate change and variability partly because they often lack adaptive capacity. The continent is particularly vulnerable to climate variability because a large proportion of the population lives in rural areas and is heavily dependent on climate-sensitive livelihoods such as agriculture – crops and livestock (Nkondze et al., 2014; United Nations Framework Convention on Climate Change-UNFCCC, 2007).

In Kenya, Global Circulation Models (GCMs) predict that global warming will lead to increased temperatures of about 4°C and cause variability of rainfall by up to 20 per cent by the year 2030. From these predictions, the two extreme climate events that may adversely affect the agricultural sector are droughts and floods in both the low, medium and high potential areas (Kabubo-Mariara and Karanja, 2006). At present, the frequency of droughts averages between two to three years compared to between five to seven year cycles experienced in the 1960s and 1970s. So far, five severe droughts have been realized over the past two decades - 1996/1997, 1999/2001, 2004/2006, 2008/2009 and 2010/2011 (KIPPRA, 2010; Government of Kenya, 2013; UNDP, 2013).

Livestock production is the mainstay of most rural households in Kenya and contributes significantly to their livelihoods. Over 60 per cent of all livestock is found in the Arid and Semi Arid Lands (ASALs), where the sub-sector employs about 90 per cent of the population. Even in the non-ASALs, the livestock sub-sector constitutes an important source of family income and food security. ASALs occupy 89 per cent of the country and are home to about 14 million people. The livestock sub-sector accounts for over 12 per cent of national Gross Domestic Product (GDP) and about 42 per cent of agricultural GDP. It also supplies the domestic requirements of meat, milk and dairy products, and other livestock products while accounting for about 30 per cent of the total marketed agricultural products. The sub-sector earns the country substantial foreign exchange through export of live animals, meat, hides, skins, dairy products and processed pork products. It also employs about 50 per cent of the country's agricultural sector labour force. The sub-sector provides raw materials for agro-industries, hence contributes substantial earnings to households through sale of livestock and livestock products (Government of Kenya, 2014; 2012).

Low and medium potential counties have large numbers of livestock, mostly in mixed systems with some degree of dairy and a significant number of free-ranging sheep and goats. The humid and sub-humid areas, however, have low concentrations of livestock due to high human population triggered by high agricultural potential and being closer to larger cities, services, markets and other infrastructure (Herrero et al., 2010). Table 1.1 below shows the livestock population in the three agro-ecological zones in Kenya.

Table 1.1: Livestock population in the different agro-ecological zones in Kenya

			Livestock population			
AEZs	**Classification**	**Counties in the AEZs**	**Cattle**	**Sheep**	**Goats**	**Camels**
Zone I & II	Humid (High potential)	Kisii, Nyeri, Kirinyaga, Meru, Bomet, Nyandarua, Kiambu, Murang'a, Kericho, Nandi, Busia Kakamega, Vihiga, Bungoma, Nyamira, Embu, Homa Bay, Uasin Gishu, Transzoia, Nakuru, Migori	5,626,651	3,316,699	2,606,021	121
Zone III & IV	Semi-humid (Medium potential)	Makueni, Siaya, Kisumu, Machakos, Taita Taveta, Kajiado, Narok, Nairobi, Tharaka Nithi, West Pokot	3,294,069	3,113,997	3,821,451	7,192
Zone V, VI & VII	Very arid to Semi-arid (Low potential)	Laikipia, Lamu, Kitui, Kwale, Mombasa, Kilifi, Baringo, Samburu, Elgeyo Marakwet, Turkana, Marsabit, Mandera, Wajir, Garissa,Tana River, Isiolo	6,894,351	8,795,984	14,556,737	2,758,805

Source: Agricultural Sector Development Support Programme, Ministry of Agriculture, Livestock and Fisheries (2013)

Livestock farming in Kenya has been constrained by poor governance of agricultural institutions, inadequate infrastructure, insufficient markets, weak marketing systems, lack of access to farm credit, high costs of farm inputs, inappropriate technology, and inadequate funding for research and extension (Food and Agriculture Organization - FAO, 2005). Some of the indirect effects are brought about by changes in feed resources linked to the carrying capacity of rangelands, the buffering abilities of ecosystems, increased desertification processes, and increased scarcity of water resources. This has led to a decrease in livestock population, which has further affected production of milk, milk products and meat (FAO, 2008).

Generally, livestock farming depends on natural systems. This makes it highly sensitive to climate change and variability, particularly changes in temperature and rainfall. High temperature degrades the resources in the rangelands and causes starvation and death of livestock. The decimation of animals has severe consequences for livestock farmers as their survival depends predominantly on their livestock (Mwiturubani and van Wyk, 2010). Rainfall, on the other hand, could benefit livestock farmers in that more rainfall could result in longer access to wet-season pasture. It could also result in less frequent drought, which may mean more time for people to rebuild their assets between lean and good times. However, there are also significant negative consequences, including loss of livestock through heat stress, loss of land to agricultural encroachment as the rise in rainfall raises the productive potential of arid areas, an increase in frequency of flooding, and the spread of human and livestock diseases that thrive during the wet and dry seasons (Oxfam International, 2008).

1.2 Problem Statement

Climate variability is acknowledged in Vision 2030 as a threat to the achievement of the annual economic growth rate of 10 per cent. If climate variability effect is unchecked, it will cause substantial damage and loss to the livestock sub-sector. Through the National Disaster Management Authority (NDMA), the Government of Kenya has focused on various short term interventions, including livestock off-take, feed provision as well as restocking programmes with the main aim of reducing the effects of climate on livestock farmers, especially in the low and medium potential areas. Despite the rigorous efforts by the government, continued loss of livestock at the household level is still a serious national concern. Extreme climatic events have persistently led to massive loss of livestock, thus negatively affecting the livestock industry and raising concerns on how to secure livelihoods for the livestock farmers. Climate variability has been known to increase abundance and distribution of livestock diseases, as well as decreased grassland productivity, which is an important enabler for animal health and productivity. If long term measures to address climate-related risks such as livestock diseases and pasture are not put in place, then the welfare of livestock farmers in Kenya is threatened (Government of Kenya, 2013).

Although climate variability is expected to affect both crops and livestock production, most of the studies concentrate on crops, disregarding the role of livestock (Di Falco et al., 2008; Deressa and Hassan, 2009; Kabubo-Mariara and Karanja, 2006). This study takes a different perspective by analyzing the effects of climate variability on livestock revenues in Kenya in order to inform policy on strategic interventions to reduce livestock losses, thereby increasing income, employment opportunities as well as boosting the welfare of livestock farmers.

1.3 Objectives of the Study

The overall objective of this study is to assess the effects of climate variability on livestock revenues in Kenya in order to explore ways of enhancing resilience in the sub-sector. The specific objectives are:

(i) To determine the extent of climate variability in Kenya.

(ii) To assess the effects of climate variability on livestock revenues in Kenya.

1.4 Research Questions

(i) What is the extent of climate variability in Kenya?

(ii) What are the effects of climate variability on livestock net revenues in Kenya?

1.5 Justification of the Study

The livestock sector has been identified as one of the growth sectors that could contribute immensely to Kenya's Gross Domestic Product (GDP). The Medium Term Plan II as well as the Kenya Vision 2030 have emphasized the significance of livestock in economic development. The findings from this study will help in designing policies and strategies, for both the national and county governments, which are geared towards hedging the livestock farmers from the extreme climatic events. This will increase the productivity of the livestock sector as highlighted in the specific strategies of Kenya's Vision 2030.

Furthermore, the economic pillar in Vision 2030 is primarily concerned with promoting export-led growth. Livestock farming for subsistence in Kenya cannot be overlooked, more so in vulnerable and highly food-insecure regions. Most of the counties in Kenya are susceptible to climate variability. The findings from this study will give insights on how livestock farmers in Kenya can reduce losses, hence help in ensuring adequate household subsistence thus reducing dependency on food aid. Similarly, implementation of the suggested recommendations will go a long way in ending the effects of drought emergencies, which has been recognized as one of the key foundations to attaining the 10 per cent growth target as envisaged in Vision 2030.

The following assumptions were made with regard to this study:

(a) It is difficult to establish the actual amount of farm size that livestock farmers use for grazing, because most of them tend to depend on public or communal land especially in the low and medium potential areas. While others depend on zero grazing especially for dairy cows (Seo and Mendelsohn, 2006b). Therefore, the dependent variable in the model is livestock revenue per farm as opposed to livestock revenue per hectare. The latter measure may introduce bias (understate or overstate the livestock revenue).

(b) Scondly, since the temperature and rainfall data were based on weather stations in the various counties, this study assumed that the households in each county experienced the same amounts of rainfall and temperature.

2. Literature Review

2.1 Theoretical Literature

This study is grounded on the profit maximization theory. This theory postulates that the farmer makes animal husbandry decisions that enhance resilience to climate variability. According to Seo and Mendelsohn (2006a), in cases of extreme weather events, a livestock farmer aims at optimizing livestock production subject to climatic constraints. In order to lower the cost, reduce the risk, and maximize profit, a farmer's decision will entail choosing the level of inputs, number of livestock and optimal combination of species that will enhance their tolerance. The decision of a farmer is pegged on profit maximization, where exogenous environmental factors such as temperature and precipitation act as individual loci beneath which the decision is made. This implies that under climate variability, the farmer must choose the most profitable animal and also the inputs that will maximize the value of that animal (Mendelsohn et al., 1994).

Therefore, the level of livestock influences the profitability. If the farmer's *i*'s profit in choosing a level of livestock *j* (*j* = 1,2,3 ..... *j*) is given as:

$$\pi_{ij} = V(Kj, Sj) + \varepsilon(Kj, Sj) \quad \text{......} 1$$

Where *K* is a vector of exogenous characteristics of the farm and *S* is a vector of characteristics of farmer *i*. For example, *K* could include climate, diseases and access variables and *S* could include farm size of the farmer and age of the farmer.

2.2 Empirical Literature

There is a growing body of empirical research done on the effects of climate change and variability on agriculture (crop) production, while there is a dearth of literature on the effects of climate change on livestock production both in Africa and Kenya (Kabubo-Mariara, 2008). Most of the studies use the Ricardian approach in measuring the effects of climate change and variability on crops and livestock.

Gebreegziabher et al. (2014) analyzed the effects of climate change and weather variation on livestock production. The study showed that temperature and rainfall greatly affect livestock revenue. Changing rainfall and temperature patterns due to climate change exhibited different effects on livestock. Increase in annual average temperature would lead to an increase in revenue from livestock while an increase in annual rainfall would have a significant negative effect on livestock revenue.

Nkondze et al. (2014) investigated the effect of temperature and rainfall on livestock production at the Mpolonjeni Area Development Programme in Swaziland. A survey of 323 sampled livestock farming households was used for analysis. Perceptions of households and climate data were used to establish climate patterns in Mpolonjeni Area Development Programme. The results of the Ricardian model showed that goats net revenue was sensitive to winter temperature, winter temperature squared, winter rainfall and winter rainfall squared. None of the climate change variables affected cattle net revenues. The study concludes that climate change affects livestock production negatively and thus livestock owners need to use climate change adaptation strategies.

Taruvinga et al. (2013) estimated the effects of climate variability and adaptations on small-scale livestock production. The study was based on a survey of 1,484 small-scale livestock rural farmers across the Eastern Cape Province of South Africa. Regression estimates found that with warming, the probability of choosing the following species increases: goats, donkeys and ducks. High precipitation increases the probability of choosing the following animals: beef cattle, goats and donkeys. Further, socio-economic estimates indicated that livestock selection choices are also conditioned by gender, age, marital status, education and household size. The paper therefore concluded that as climate changes, rural farmers switch their livestock combinations as a coping strategy. Unfortunately, rural farmers face a limited preferred livestock selection pool that is compatible to harsh climate, which might translate to a bleak future for rural livestock farmers.

Gebreegziabher et al. (2013) looked into the economic effects of climate change and variability on agricultural production. Climate change and agricultural productivity in Ethiopia was analyzed in a broader sense, inclusive of livestock production. A Ricardian approach was used to estimate the effects of climate change and variability on both crops and livestock. The results showed that warmer temperature is beneficial to livestock production. Moreover, increasing/ decreasing rainfall damage livestock. As far as the socio-economic variables are concerned, access to formal extension services and level of education of household head turned out to be significant. Distance to input markets also remained significant but negative. Farm size turned out significant and positive.

Seo and Mendelsohn (2008) used a cross-sectional approach to analyze the effects of temperature and rainfall variations on animal husbandry and the way farmers adapt. The study was based on surveys of almost 5,000 livestock farmers across ten countries in Africa. A Ricardian regression found out that the livestock net revenues of large farms in Africa are more sensitive to temperature than those of small farms. Cross-sectional analysis also revealed that warming increases income on small farms by US$ 100 per degree. For large farms, warming reduces income by US$ 330 per degree. The temperature elasticity of small farms is about +24 whereas the temperature elasticity of large farms is -2.3. A marginal increase in precipitation reduces net revenue per farm for both small and large farms. Small farms decline by about US$ 20 per mm of monthly precipitation and large farms by about US$ 65 per mm, and both effects are significant. The precipitation elasticity is about -13 for small farms and -1.2 for large farms. Small farms have such a large elasticity because they shift from livestock to crops. All livestock farms have a negative elasticity with precipitation because natural ecosystems shift from grasslands to forests, and there is an increased prevalence of animal diseases such as trypanosomiasis.

Kabubo-Mariara (2008) focused on the economic impact of global warming on livestock production in Kenya. The main data for this study were based on a sample of 722 households. The data were collected from six out of eight provinces between June and August 2004. The study also made use of satellite and ARTES (Africa Rainfall and Temperature Evaluation System) climate data. The Ricardian regression results showed that livestock production in Kenya is highly sensitive to climate change, and that there is a non-linear relationship between climate change and livestock productivity. The estimated marginal impacts suggested very modest gains from rising temperatures; for instance, a 1 unit rise in temperature would result in approximately 5 per cent increase in net livestock revenue. In addition, increased precipitation will lead to a fall in the net value of livestock; that is, a 1 per cent rise in rainfall would lead to between 1.35 per cent and 1.19 per cent decline in livestock net value. Age of household head remained significant but negatively correlated with livestock net incomes.

Kurukulasuriya et al. (2006) analyzed the economic effects of temperature and rainfall on African agriculture using data from a survey of more than 9,000 farmers across 11 African countries. A cross-sectional approach estimated how farm net revenues are affected by climate change compared with current mean temperature. The results showed that revenues fall with warming for dry land crops (temperature elasticity of -1.9) and livestock (-5.4). This clearly shows that livestock are highly vulnerable to increasing temperature as compared to crops. On the other hand, increase in precipitation will lead to elasticity of 0.4 for dry land crops and 0.8 for livestock across Africa. Generally, increases in precipitation will have an unambiguously beneficial effect on African farms on average, whereas decreases in precipitation will have a harmful effect.

2.3 Synthesis of Literature

Two key issue stand out from the literature review drawn from Kenya. First, climate variability is a real threat to livestock production. Thus, there is urgent need to come up with policies and interventions geared towards the anticipated effects of climate variability for the specific agro-ecological zones. Secondly, a study done in Kenya on the impact of climate change on livestock production excluded North Eastern counties, yet it is a region with the highest livestock population as per the 2009 census. There is need, therefore, to undertake a study that covers these areas.

2.4 Review of Literature on Choice of Approach/Methodology

There are two approaches that can be used to estimate the effects of climate change on livestock - the production function approach and the Ricardian approach. The traditional studies have used the production function approach (Rosenzweig and Iglesias, 1994). This approach relies upon empirical or experimental production function to predict environmental damage. The approach has been criticized, since it over-estimates the damage of climate change on farming because of failing to take into account the infinite variety of substitutions, adaptations and old and new activities that may displace obsolete activities as climate changes (Kabubo-Mariara and Karanja, 2006).

Most studies use the Ricardian approach in estimating the impact of climate change on agriculture (Mendelsohn et al., 1994). The Ricardian approach is based on the original observation by David Ricardo (1772-1823) that land rents reflect the net productivity of farmland, and it examines the impact of climate and other variables on land values and farm revenues (Ricardo 1817, 1822). Since 1994, studies on climate change and agriculture that used the Ricardian model have been undertaken. The model can be used to analyze the cross-sections of farms under different climatic conditions, and examines the relationship between the net revenue (Mendelsohn et al., 1994; Kabubo-Mariara and Karanja, 2006; Gebreegziabher et al., 2013) and climatic factors (Mendelsohn et al., 1994), soils and socio-economic variables. The model has been applied to value the contribution of environmental factors to farm income by regressing farm performance, with net revenue taken as dependent variables on a set of independent variables, including environmental factors, inputs (land and labour) and support systems (infrastructure). Besides measuring the contribution of each factor, the Ricardian approach is also used to detect the effects of long-term climate change on farm values (Mendelsohn et al., 1994; Gebreegziabher, 2013).

The Ricardian model was initially applied in the context of developed countries in general and US agriculture in particular (Mendelsohn et al., 1994). It has recently been applied in specific developing countries. Some of these recent studies include Deressa and Hassan (2009), Kurukulasuriya and Mendelsohn (2006), Kabubo-Mariara and Karanja (2006) and Gebreegziabher (2013). Surprisingly, most of these studies have shown that agriculture in developing economies is very susceptible to climate change and variability. Most of these studies also reveal that the magnitude and direction of the effect may differ from one region to another.

The Ricardian approach has been criticized by different scholars. Some of the criticisms include: First, the approach does not measure transition costs, where a farmer changes from one livestock species to another suddenly, yet transition costs are clearly very important in sectors where there is extensive capital that cannot easily be changed. Second, it generally assumes prices to be constant, which introduces bias in the analysis, over-estimating benefits and under-estimating damages. Mendelsohn et al. (1994) have shown that the Ricardian model is useful for predicting the impact of climate change because the way farmers respond to alternative climate scenarios over space is the same way that farmers will respond in the long run to those same changes in climate over time.

In spite of these criticisms, increased evidence has shown that the bias introduced by the Ricardian assumptions is likely to be small (Kurukulasuriya and Mendelsohn, 2006). This approach has been found to be useful because it corrects the bias in the production function approach (Rosenzweig and Iglesias, 1994). By directly measuring farm prices or revenues, the approach also accounts for the direct effects of climate on the yields of different crops and livestock, as well as the indirect substitution of different inputs, the introduction of different livestock types and other potential adaptations to different climates (Mendelsohn et al., 1994). It is also attractive because it includes not only the direct effect of climate on productivity, but also the adaptation response by farmers to local climate. This study will therefore use the Ricardian approach.

2.5 Government Interventions on Livestock Sub-sector

Over the years, the Kenyan government has established various interventions in the livestock sector with the main aim of enhancing resilience to the effects of climate change and variability. Of importance is the 'up-grading' of indigenous animals towards the exotic breeds with the intention of increasing production. However, this has resulted in suppression of the indigenous genetic material important for adaptability, hence the emergence of crossbreeds that are not as equally adapted to the local environment as the indigenous breeds (Government of Kenya, 2014).

The most significant interventions for medium and low potential areas was the establishment in 2008 of the Ministry of State for Development of Northern Kenya and other Arid Lands (MNKOAL), renamed (Directorate of Arid and Semi-Arid Lands) under the Ministry of Devolution and Planning. The Directorate has spearheaded significant policy and institutional reforms to address the development challenges facing the ASALs. With renewed interest in livestock production, the Kenyan government has established the National Drought Management Authority (NDMA), which is under the Directorate, to assist pastoral communities during hard times such as droughts. This has been done by providing support to livestock farmers through food aid, emergency livestock off-takes and re-stocking programmes (Government of Kenya, 2014).

Despite the government interventions in the early warning systems and livestock off-take programmes, climate change and variability has continued to affect livestock more so in the low and medium potential areas. There are several different but related challenges. First, the most appropriate time to invest in resilience is when conditions are good. However, substantial finance is generally triggered by crisis rather than by normality. Second, the allocation of budgets, whether from government or its development partners, remains weighted towards emergency response. Third, decision-making on early warning information is slow and cumbersome, such that funds are released too late in the drought cycle to mitigate its impacts. Fourth, the significant resources that the government makes available are channelled through each sector's normal financing and procurement channels, which are not nimble enough to support timely action (Government of Kenya, 2013).

Generally speaking, it is clear that the Government of Kenya has focused on short term measures to counter the effects of climate change and variability. There is need, therefore, to come up with long term interventions such as establishment of disease free zones in the affected areas as well as the development of grassland productivity and infrastructure. This will go a long way in building resilience to climate variability by improving animal health and productivity, thereby ensuring access to local, regional and international markets.

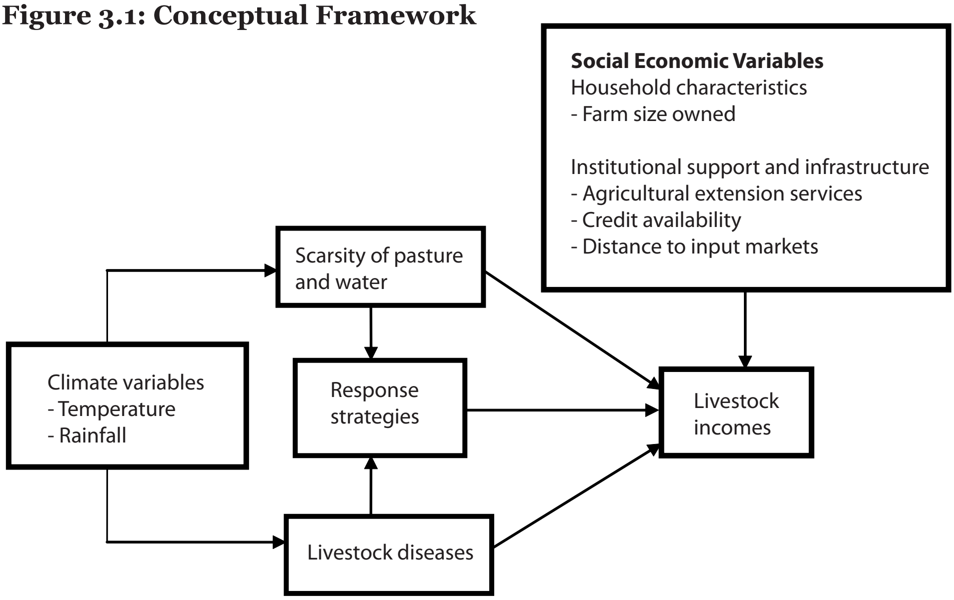
3. Methodology

3.1 Conceptual Framework

The conceptual framework presented in Figure 3.1 shows the linkages between climate variables and livestock revenues. The climate variables (temperature and rainfall) affect livestock revenue either positively or negatively. Increased temperatures cause scarcity of pasture and water. These results in emaciated animals, which fetch lower prices in the market hence lower livestock net revenue. On the other hand, increased rainfall guarantees plenty of water and pastures, hence increased livestock production thereby fetching higher revenue while extreme rainfall is disastrous to livestock because of diseases breakouts associated with high rainfall. Due to extreme climatic events (high temperature and rainfall), livestock farmers are forced to respond through migration, herd accumulation, livelihood diversification, feed conservation, intensification of animal diseases, among other ways, in order to cushion themselves against these events (Kabubo-Mariara, 2005; FAO, 2010; Nkedianye et al., 2011).

Socio-economic variables (household characteristics, institutional support, and infrastructure) also play a key role in livestock revenues. The size of farms owned, access to agricultural extension services, credit as well as distance to output markets may trigger higher livestock revenues.

Figure 3.1: Conceptual Framework



Source: Author's conceptualization

3.2 Analytical Framework

To analyze the effect of climate variability on livestock production in Kenya, this study uses a Ricardian analysis. Following Seo and Mendelsohn (2006a), we start by assuming that the farmer maximizes net income by choosing which level of livestock holding to keep and which inputs to apply:

$$Max\ \pi = P_{qj}\ Q_j(L_G, S, H, K, F, A, Z) - P_F F - P_L L - P_K K \text{ ....(1)}$$

Where:

π is livestock net revenues

P_{qj} is the market price of animal *j*

Q_j is a production function for animal *j*

L_G is grazing land

F is feed

L is a vector of labour inputs

K is a vector of capital inputs

C is a vector of climate variables

W is available water

S is a vector of soil characteristics

P_F is a vector of prices of each type of feeds

P_L is a vector of prices for each type of labour, and

P_K is the rental price of capital.

The farmer chooses the number of animals that maximizes profit. The resulting income can be defined as:

$$\pi^* = f(P_q, C, W, S, P_F, P_L, P_K) \text{ ....(2)}$$

The Ricardian function is derived from the profit-maximizing level of equation (2) and explains how profits change across all the exogenous variables facing a farmer. The change in welfare (ΔU) resulting from climate change from C_o to C_1 can be measured using the Ricardian function as follows:

$$\Delta U = \pi^*(C_1) - \pi^*(C_o) \text{ ....(3)}$$

The Ricardian model treats a farmer as though he is an income generating entity. Seo and Mendelsohn (2006a) have shown that although this assumption fits large farms, it can be applied to small farms by addressing issues of valuation of household labour and own consumption. This Ricardian approach has been found attractive because it corrects the bias in the production function approach (Rosenzweig and Iglesias, 1994) by using economic data on the value of land, by directly measuring farm prices or revenues. The Ricardian approach accounts for the direct effects of climate on the yields of different livestock, as well as the indirect substitution of different inputs, the introduction of different activities/livestock species, and other potential adaptations to different climates (Mendelsohn et al., 1994). It is also attractive because it includes not only the direct effect of climate on productivity but also the adaptation response by farmers to local climate.

In this paper, the revenue of livestock is estimated. The final model is specified as:

$$\pi = \alpha_0 + \alpha_1 Temp + \alpha_2 Temp^2 + \alpha_3 Rainf + \alpha_4 Rainf^2 + \alpha_5 LivD + \alpha_6 FarmS + \alpha_7 AgriA + \alpha_8 CreditA + \alpha_9 Dmkts + \alpha_{10} FeedC + \varepsilon \quad \text{.....................................(4)}$$

Where:

π is livestock revenue

Temp and $Temp^2$ capture the linear and quadratic terms for temperature

Rainf and $Rainf^2$ capture linear and quadratic terms for rainfall

LivD is a vector of livestock diseases shocks

FarmS is the farm size owned

AgriA is the access to agricultural extension

CreditA is the access to credit

Dmkts is the distance to markets

FeedC is the feed conservation

$\alpha_0 - \alpha_{10}$ are coefficients

ε is the disturbance term

The quadratic terms for temperature and rainfall are expected to capture the non-linear shape of the climate response function. When the quadratic term is positive, the revenue function is U-shaped, but when the quadratic term is negative, the function is hill-shaped. From equation (4), we can derive the expected marginal impact of temperature and rainfall changes on livestock production as in equations (5) and (6), respectively;

$$E(\,) = \alpha_1 + 2\,\alpha_2\, E\,(Temp) \quad \text{..(5)}$$

$$E(\,) = \alpha_3 + 2\,\alpha_4\, E\,(Rainf) \quad \text{..(6)}$$

Cross-sectional data usually provide major econometric problems such as outliers, multicollinearity, heteroscedasticity, and endogeneity of explanatory variables. In light of the fact that these econometric issues are likely to affect the robustness of the regression results, the following measures were undertaken: Outliers were dropped from the model by truncating the top 20 per cent and the bottom 20 per cent; and hettest test was undertaken for heteroscedasticity and variance inflation factor for multicolinearity. The model was finally run in a reduced form. This ensures that the X matrix is uncorrelated with the error term, hence solving the problem of endogeneity.

3.3 Data Types and Sources

Household data: The dataset used for this study was obtained from a cross-sectional Agricultural Sector Development Support Programme (ASDSP) household baseline survey carried out by the Kenya Agriculture and Livestock Research Organization (KALRO) in collaboration with the University of Nairobi for the implementation of ASDSP during the 2012/13 financial year. The study made use of data from 44 counties in Kenya. Three cities - Nairobi, Mombasa and Kisumu - were excluded due to urbanization. The households from the different counties were classified into three agro-ecological zones - low potential, medium potential and high potential. A total of 10,341 observations were considered for analysis.

Climate data: Data on temperature and rainfall was obtained from the Kenya Metrological Department (KMD). This dataset captured average annual temperature and rainfall data from weather stations in all the counties in Kenya. This data was then categorized into the 44 counties to make it compatible with the household data.

3.4 Variables and Method of Analysis

In this paper, the dependent variable is livestock revenue. Independent variables included the linear and quadratic temperature and rainfall, livestock disease shocks, socio-economic factors (household characteristics - farm size owned, institutional support and infrastructure access, to livestock extension services, credit and distance to output markets) and a response strategy-feed conservation. STATA version 13 was used for analysis.

Table 3.4: Definition of variables used for empirical analysis

Symbol	Description of variables	Measurements	Expected sign
FarmS	Farm size owned	Acres	(+/-)
AgriA	Access to agricultural extension access	1=Yes: 0=No	(+)
CreditA	Access to credit	1=Yes: 0=No	(+)
Dmkts	Distance to output markets	Kilometers	(+/-)
LivD	Livestock disease shock	1=Yes: 0=No	(-)
FeedC	Feed conservation	1=Yes: 0=No	(+)
Temp	Average annual temperature	Degrees Celsius	(+/-)
Rainf	Average annual rainfall	Millimeters	(+/-)
$Temp^2$	Temperature squared	Degrees Celsius	(+/-)
$Rainf^2$	Rainfall squared	Millimeters	(+/-)

4. Results and Discussion

4.1 Descriptive Statistics of Variables

This section presents the results and discussions from empirical estimation of the Ricardian analysis. Table 4.1 presents the descriptive statistics of the variables used in the analysis. The results clearly show that the annual livestock revenue was approximately Ksh 75,292. The mean annual temperature and rainfall was 21.05°C and 100.33 mm, respectively. Nearly 70 per cent conserved livestock feeds. The mean distance to input and output markets was 6.08 and 18.51 kilometers, respectively. Approximately 20 per cent of the livestock farmers had access to agricultural extension services while only 3 per cent had access to credit. About 56 per cent of the livestock farmers experienced diseases shock. The mean land size was 44.49 acres.

Table 4.1: Descriptive statistics of selected variables

Descriptive Statistics	Mean	Standard Deviation
Farm size owned	44.4876	575.4039
Disease shock	0.5575	0.4967
Agricultural extension access	0.2018	0.4016
Credit access	0.0340	0.1959
Distance to input markets	6.0830	9.8566
Distance to output markets	18.5142	21.1711
Feed conservation	0.7010	0.2568
Temperature average	21.0504	4.7492
Rainfall average	100.3347	52.7360
Livestock incomes	75,292.4	794,183.7

4.2 Climate Variability in Kenya

From Table 4.2 below, the low potential areas had a significantly higher average temperature compared to medium and high potential areas. The variability of temperature as measured by the standard deviation was also highest in low potential areas. This implies that the low potential areas are mostly affected by temperatures as compared to high potential areas. On the other hand, high and medium potential areas had a higher average rainfall compared to low potential areas. Similarly, rainfall variability was also highest in the high potential areas as compared to low potential areas.

Table 4.2: Climate variability across the three agro-ecological zones in Kenya

Climate variables	Category	N	Mean	Standard Deviation	f-stat (p value)
Average temperature	Low Potential	2,378	25.7256	4.833182	f=3280.8 (p=0.000)
	Medium Potential	1,690	20.80249	2.74068	
	High Potential	6,273	19.04525	2.908059	
	Total	10,341	20.86864	4.378316	
Average rainfall	Low Potential	2,378	46.03644	26.85733	f=4830.4 (p=0.000)
	Medium Potential	1,690	71.3079	28.39735	
	High Potential	6,273	132.0121	44.89524	
	Total	10,341	102.3206	54.22855	

4.3 Livestock Disease Shocks in Kenya

As far as the livestock disease shock is concerned, the results indicate that there exists an indirect/mediating effect of climate variability on livestock revenue. The mediating effect is revealed by observation that agro-ecological zones with highest variability in climate are also the ones with the highest incidence of livestock diseases as indicated in Table 4.2 and 4.3. The implication, therefore, is that climate variability affects livestock revenue by increasing the incidence of livestock diseases. It is therefore critical to put more emphasis on areas with high climate variability, since livestock revenue would suffer from the twin effect of climate variability and livestock diseases.

Table 4.3: Livestock diseases shocks across the three agro-ecological zones in Kenya

Variable	Category	N	Mean	Standard Deviation	f-stat (p value)
Livestock diseases shocks	Low Potential	2,378	0.64	0.48	f=71.204(p=0.000)
	Medium Potential	1,690	0.60	0.48	
	High Potential	6,273	0.51	0.50	
	Total	1,0341	0.55	0.49	

4.4 Effects of Climate Variability on Livestock Revenues

In this paper, the livestock revenue is a function of four sets of regressors: (i) climate variables (ii) livestock disease shock (iii) socio-economic variables (household characteristics, institutional support and infrastructure) (iv) response strategies. The results showed that climatic variables (temperature and rainfall) have significant effects on farm revenue in Kenya. In other words livestock revenue is negatively affected by increases in both temperature and rainfall.

The study estimated the effect of climate variability on value of livestock per farm. Results for linear and quadratic temperature and rainfall, livestock diseases, socio-economic variables and response strategies were presented as shown in (Table 4.4).

Table 4.4: Ricardian regression estimates for livestock net income model

Variable	Low potential	Medium potential	High potential
Temperature	-0.4849 (-3.46)*	-6.3650 (-12.58)*	-0.1532 (-2.50)*
Temperature sq	0.01386 (4.61)*	0.1394 (12.47)*	0.0017 (0.96)
Rainfall	-0.05712 (-4.92)*	-0.2072 (-4.49)*	0.0114 (2.07)*
Rainfall sq	0.00046(4.74)*	0.00127 (4.73)*	-0.00004 (-2.35)*
Livestock diseases	-1.4189 (-12.63)*	-0.4723 (-6.13)*	-0.4585 (-11.04)*
Farm size owned	0.0095 (1.80)	-0.4723 (0.52)	0.0086 (7.73)*
Agricultural extension access	-0.3857(-1.93)	-0.367 (-0.37)	0.1716142 (3.64)*
Credit access	0.05129 (0.16)	-0.01790 (-0.70)	0.287045 (3.50)*
Distance to output markets	-0.02559(-10.18)*	-0.0440 (-20.46)*	-0.0198 (-20.21)*
Feed conservation	0.3678 (2.37)*	-0.0145 (-0.13)	0.4225 (7.61)*
F	35.63	109.16	95.21
Prob>F	0.0000	0.0000	0.0000
R-Squared	0.2546	0.4894	0.2019
Adj. R-Squared	0.2475	0.4849	0.1998
Root MSE	1.5833	1.2654	1.228
n	1,054	1,150	3,775

**Denotes significance at 95 %*

The analysis in (Table 4.4) displays three model results. The second column highlights the model results for low potential areas, the third column presents the results for medium potential areas, and the fourth column captures the results of high potential areas.

As far as the linear terms are concerned, results showed that high temperature is significant and negatively affects livestock revenue for all the three zones. This is because high temperature leads to degradation of the natural resources such as pasture and water. As a result of this, the livestock health and productivity is compromised, thereby fetching lower prices in the market and hence lower livestock revenue. In addition, high temperatures will force livestock farmers to sell their stocks or risk losing them.

Similarly, linear rainfall exhibits a negative relationship with livestock income for low and medium potential areas. The negative effect of the linear term implies that increasing rainfall would result to damage in the stocking levels of the livestock. This is consistent with findings by Seo and Mendelsohn (2006b), which show that livestock production in Africa is quite sensitive to changes in rainfall. The justification for this are in threefold: first, with increasing rainfall, it is most likely that livestock farmers are likely to switch from livestock to crops due to the conducive environment for crop production. This is consistent with the findings by Kabubo-Mariara (2008). Secondly, high rainfall leading to floods is associated with livestock diseases such as Rift Valley Fever, which significantly reduce the levels of livestock and consequently the revenues. Thirdly, heavy rains cause livestock losses as animals drown. This has been experienced in Kenya in the past, where extremely heavy rains sweep away animals. For the high potential areas, the linear rainfall is significant and positive; this means that high rainfall increases livestock revenue. This could be because the high potential areas are not prone to floods and has better infrastructure for disease control.

The quadratic terms of temperatures and rainfall are significant for both the low and medium potential areas. Both the temperature and the rainfall show a downward trend. This implies that the increasing temperature and rainfall will not auger well for livestock farming in Kenya except for high potential areas, confirming that climate variability has devastating effects on livestock unless livestock farmers practice adaptation strategies to counter the effects of increasing temperatures and rainfall. The quadratic rainfall in high potential areas shows an upward trend, meaning that it is beneficial to livestock production.

Livestock diseases turned out negative and significant for all the three agro-ecological zones. Prevalence of livestock diseases was highest in low potential areas followed by medium potential while high potential areas experienced low incidences of diseases. Livestock diseases were inversely correlated with livestock revenue, which implies that these diseases had a negative effect on livestock revenue. From the results, the occurrences of livestock diseases lower the quality of meat, hides, skin and other animal products, thereby fetching low prices in the market. Furthermore, livestock diseases hinder the capacity of Kenya to export beef and other livestock products to markets in Middle East, Europe and other international markets.

Among the variables, farm size owned by the households in high potential areas was significant and positive. This implies that smaller farms realized higher revenues due to intensive livestock farming as compared to large farms in the medium and low potential areas. Access to agricultural extension and credit services was significant, and positively affects livestock revenue for high potential areas because these services enable the farmers to buy more livestock and adhere to proper livestock husbandry practices, thereby increasing revenues. Access to agricultural extension and credit was, however, not significant for both the low and medium potential areas. This could be because the majority of the livestock farmers in these areas do not have access to the above mentioned services.

Distance to output markets turned out negative and significant, showing that it was inversely correlated with livestock revenue, possibly because livestock keepers incur more transaction costs in terms of money as they transport livestock from their farm gates to the output markets. Feed conservation turned out positive and significant for both the low and high potential areas, supporting the fact that increased adaptation strategies such as feed conservation is associated with increased livestock productivity and revenue. Feed conservation for the medium potential areas was negative and not significant. This could be because the farmers in these areas spend money to conserve feeds, which they may end up not utilizing due to the availability of pastures throughout the year.

4.5 Marginal Effects of Climate Variables on Livestock Revenues

The Ricardian model results for the marginal effects of climate variables on livestock revenues are presented in Table 4.5. The results showed that increase in temperature would be harmful to livestock activities in the country. Increase in temperature by 1 per cent would decrease the livestock farm revenue by about 0.48 per cent, 6.36 per cent and 0.15 per cent for low, medium and high potential areas, respectively.

Similarly, an increase in rainfall is destructive to livestock production for low and medium potential areas. Increase in rainfall by 1 per cent would reduce the livestock farm revenue by about 0.05 per cent for low potential areas and 0.20 per cent for medium potential areas. Increase in rainfall leads to increase in livestock revenues for high potential areas; that is, increase in rainfall by 1 per cent would increase the livestock farm revenue by about 0.01 per cent.

Table 4.5: Marginal effects of climate variables

Climate Variables	Low potential	Medium potential	High potential
Temperature	-0.4824 (-3.46)	-6.3650 (-12.58)	-0.1532 (-2.50)
Rainfall	-0.05712 (-4.92)	-0.2072 (-4.49)	0.0114 (2.07)
P=0.05			

5. Conclusion and Policy Recommendations

5.1 Conclusion

This study attempts to assess the economic effects of climate variability on livestock production in Kenya using the Ricardian model. The conclusions that can be drawn from the findings of the study are that: first, low and medium potential areas had a significantly higher average temperature compared to high potential areas. The variability of temperature was also highest in low and medium potential areas. On the other hand, high potential areas had a higher average rainfall compared to the medium and low potential areas. Since temperature has greater effect than rainfall (Table 4.4; 4.5), it is expected that the low potential areas will be greatly hit by the increasing temperatures as compared to high potential areas.

Secondly, the results clearly show that climate affects livestock revenues. Increased temperatures and rainfall lead to decline in livestock revenue. The results further showed that there is a non-linear relationship between temperature and livestock net revenue, and between rainfall and livestock revenue. This finding is consistent with studies on the effects of global warming on agriculture (Mendelsohn et al. 1994; Kurukulasuriya and Mendelsohn, 2006). High temperature reduces grassland productivity, leading to decline in animal health and productivity, thereby fetching lower prices in the market, hence lowering the revenue. Higher temperatures will also force the livestock keepers to sell their stocks or risk losing them. As far as increasing rainfall is concerned, livestock farmers may switch from livestock to crops due to the conducive environment for crop production. High rainfall also causes floods and livestock diseases such as Rift Valley Fever, which significantly reduce the levels of animals and consequently the livestock revenues. Furthermore, the results showed that farm size owned and feed conservation are positively correlated with livestock revenue, while livestock diseases and distance to output markets are inversely correlated with livestock revenue.

Third, the marginal effects of climate variables showed that increase in temperature would be disastrous to livestock activities in Kenya. An increase in temperature by 1 per cent would decrease the livestock revenue by about 0.48 per cent, 6.36 per cent and 0.15 per cent for low, medium and high potential areas, respectively. Equally, an increase in rainfall by 1 per cent would reduce the livestock revenue by about 0.05 per cent for low potential areas and 0.20 per cent for medium potential areas while it increases livestock revenues for high potential areas by 0.011 per cent.

5.2 Policy Recommendations

Based on the research findings, the study suggests the following policy recommendations:

(i) Establish county livestock enterprise fund

The county governments should create their own financing mechanisms, including disaster funds such as county livestock enterprise fund to build the capacity of the livestock farmers to manage climate variability episodes more efficiently, and thus facilitate early response.

(ii) Establish disease free zones

Since the low and medium potential areas have large numbers of animals and are badly affected by livestock diseases, the national government in collaboration with the county governments should establish disease free zones by strengthening disease surveillance, monitoring and control as well as providing rapid response to disease outbreaks. There is need to improve the infrastructure for disease control and animal handling, such as cattle dips, spraying races as well as quarantine stations. This will ensure quality beef, hides and skins and hence ensure adherence to international sanitary requirements on trade in animals and animal products, thereby maintaining markets that have been gained especially in Middle East and Europe.

(iii) Establish livestock marketing infrastructure

The government through the Kenya Meat Commission (KMC) should facilitate livestock marketing so as to increase household income and contribute to poverty reduction. KMC should construct livestock marketing infrastructure such as abattoirs in the low and medium potential areas so as to lower transport cost by farmers and also reduce the spread of diseases.

(iv) Encourage and enhance feed conservation and strategic feed reserves

The county governments should play a lead role in encouraging strategic activities to reduce the effects of climate variability. They need to invest resources in equipping farmers so as to cushion them against further adverse climatic conditions. For instance, feed conservation should be introduced to livestock farmers and adoption encouraged, more so in the low and medium potential areas. Furthermore, there is need to increase strategic storage facilities and feeds to facilitate enough animal feedstuffs during periods of scarce pasture. This will in turn increase livestock production and revenue and at the same time reduce migration in search of the same.

(v) Encourage drought tolerant livestock breeds

As the government strives to improve livestock production through livestock upgrading programmes, efforts should also be made to encourage the promotion of drought tolerant livestock, which are well adapted and resilient to the effects of climate variability.

5.3 Areas for Further Research

This study analyzed the economic effects of climate variability on livestock revenues using the Ricardian approach, but did not explore any welfare effects on the same. Future research should therefore focus on the effect of climate variability on the welfare of livestock farm households in Kenya.

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